SHRP2 R02—Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Pavement Working Platform

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ABSTRACT

The second Strategic Highway Research Program (SHRP2) was created by the U.S. Congress to address challenges of moving people and goods efficiently and safely on the nation’s highways. Geotechnical transportation issues are addressed under the SHRP2 Renewal Focus Area, in which the goal is to develop a consistent, systematic approach to the conduct of highway renewal that is (1) rapid, (2) causes minimal disruption, and (3) produces long-lived facilities. Although in existence for several decades, many geoconstruction technologies face both technical and non-technical obstacles, preventing broader and more effective utilization in transportation infrastructure projects. SHRP2 R02 is investigating the state of practices of transportation project engineering, geotechnical engineering, and earthwork construction to identify and assess methods to advance the use of these geoconstruction technologies. The identified technologies are often underutilized in current practice, and they each offer significant potential to achieve one or more of the three SHRP2 Renewal objectives listed earlier. Project R02 encompasses a broad spectrum of materials, processes, and technologies within geotechnical engineering and geoconstruction that are applicable to one or more of the following “elements” of construction: (1) new embankment and roadway construction over unstable soils, (2) roadway and embankment widening, and (3) stabilization of pavement working platforms.

Phase 1 of the project, completed in August 2008, consisted of six tasks focused on identifying those geotechnical materials, systems, and technologies that best achieve the SHRP2 Renewal strategic objectives for the three elements. Explicit in the tasks was the identification and evaluation of technical issues, project development/delivery methods, performance criteria and quality assurance and control (QA/QC) procedures, and non-technical issues that constrain full utilization of geotechnical materials, systems, and technologies. A total of 47 applicable geoconstruction technologies were identified in the Phase 1 work. Seventeen technical issues and project development pros and cons were identified that interfere with more widespread use of geoconstruction technologies. Fifteen non-technical issues and project specific parameters limiting use of the technologies were identified. In addition to identification of issues and obstacles, Phase 1 included the identification of the most promising mitigation methods to overcome the obstacles.

Phase 2 of the project includes evaluation of the effectiveness of mitigation measures; a catalogue of materials and systems for rapid renewal projects; guidance for design and QA/QC procedures; methods for estimating costs; and sample specifications for the identified geotechnical materials, systems, and technologies. The research team proposes to incorporate the development of the catalogue and the requirements for guidance on design, QA/QC, costs, and specifications into an integrated catalogue and guidance system. This system will provide the data necessary for determining the applicability of specific...
technologies to specific projects and will guide the user to information needed to apply the selected technologies. The catalogue will include information necessary for initial screening as well as design methodologies, QA/QC, costs, and specifications.

Key words: geoconstruction—geotechnical—Renewal objectives
SHRP2 R02 Phase 1—Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Working Platform

Vern Schaefer – Iowa State University

Mid-Continent Transportation Symposium
August 20–21, 2009
Ames, Iowa
Presentation Outline

- Background on SHPR2 RO2
- Phase 1 Results
- Phase 2
- Q & A
RO2. Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction and Stabilization of the Pavement Working Platform

Prime contractor: Iowa State University
Budget: $3,000,000
Duration: 48 months
Contract Start Date: September 25, 2007

Anticipated Products

• Mitigation measures to overcome obstacles to more widespread use of soil improvement technologies
• Guidelines and methods for selection, design, QC/QA, costs, and specifications for soil improvement technologies applied to:
  ❖ New embankments and roadways over unstable soils (Element 1)
  ❖ Embankment widening (Element 2)
  ❖ Stabilization of base, sub-base, and subgrade layers (Element 3)
What are Geotechnical Solutions?  
*Construction Options*

- Geoconstruction/Ground Improvement Methods and Systems
  - Geotechnical construction methods to alter poor soil/ground conditions to meet project requirements.
  - Methods to
    - Increase bearing capacity or strength
    - Increase density
    - Control deformations
    - Accelerate consolidation
    - Decrease imposed loads
    - Reduce permeability and seepage
    - Increase resistance to liquefaction
  - Can be accomplished by variety of methods, often categorized by densification, reinforcement or stabilization.
Project Scope

Phase 1 Report (August 2008)
- Searchable documentation of the identified geotechnical materials and systems addressed
- Information on how to locate and access documentations of case histories
- Reference materials and other supporting documentation.
- Updated Phase 2 Research Plan

Phase 2 Report (September 2011)
- Mitigation measures
- Catalog of materials and systems for rapid renewal projects
- Sample design procedures, QA/QC processes, and guidelines
- Tools for estimating the costs of application
- Sample guide specifications for geotechnical materials and systems
SHRP2 R02 Elements

1. Construction of new embankments and roadways over areas of unstable soils
2. Widening and expansion of existing roadways and embankments
3. Improvement and stabilization of the support beneath the pavement structure.
Project Objectives

- Identify existing alternative materials and systems for constructing embankments and roadways over unfavorable ground conditions.
- Develop or compile design guidelines, procedures, and QA/QC test procedures for construction of ground improvements.
- Develop performance-based construction specifications for selected soil improvement technologies.
- Determine which existing and emerging technologies offer promise for treating areas of unfavorable subsurface conditions.
Project Team & Management Plan

SHRP2 RO2 Program

James Mitchell, Sc.D., P.E.
Virginia Tech
Senior Technical Advisor

Vernon Schaefer, Ph.D., P.E.
Iowa State University
PI and Project Manager

Ryan Berg, Ph.D., P.E.
Ryan Berg & Associates, Inc.
Co-PI and Co-Project Manager

Element I
George Fitz, Ph.D., P.E.
Virginia Tech
Co-PI and Element Co-Leader

Donald Bruce, C. Eng., L.E.G., L.G.
GeoSystems L.P.
Co-PI and Ground Improvement Specialist

Element II
James Collin, Ph.D., P.E.
The Collin Group
Co-PI and Element Co-Leader

Jie Han, Ph.D., P.E.
University of Kansas
Co-PI, Ground Improvement and Working Platform Specialist

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David White, Ph.D.
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Geotechnical Consultant
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Gery Fick, M.S.
Tony Construction Management Services, Inc.
Task Specialist: Contracting Strategies and Methods

Dennis Turner, P.E.
The Transpec Group, Inc.
Task Specialist: Pavement Evaluation and Design

Limbing Wang, Ph.D.
Virginia Tech
Task Specialist: Pavement Evaluation and Design

Advisory Panel
State DOT Representatives
Contractor Representatives
Private Design Professionals
Trade/Professional Associations

Expert Contact Group
Advisory Board Members

State DOT Representatives
James Brennan, Kansas DOT
David Horhota, Florida DOT
Mark Morvant, Louisiana TRC
Hooshmand Nikoui, Caltrans
David Shiells, Virginia DOT
John Siekmeier, Minnesota DOT

Design/Build Contractor Representatives
Allen Cadden, Schnabel Engineering, North, LLC
Mike Cowell, GeoConstructors, Inc.
Seth Pearlman, DG1-Menards, Inc.
Steve Saye, Kiewit Engineering
Al Sehn, Hayward Baker Inc.
Phase 1 Overview

- Results
- Process
- Task 1 – List technologies & categorized bibliography
- Task 2 – Technical Issues
- Task 3 – QA/QC procedures
- Task 4 – Constraints
- Task 5 – Mitigation Strategies
- Task 6 – Report & Phase 2 Plan
Phase 1 Results

• Seven documents/reports
  1. Results of Updated Survey of Technology Applicability and Potential
  2. Phase 1 Workshop Report
  3. Technology Assessment Instructions
  4. Technology Assessments
  5. Literature Review Database
  6. Documentation of Approach to Assessment of Technologies and Mitigation Strategies
  7. Phase 1 Report including Updated Work Plan for Phase 2
Phase 1 Process

- Collaborative, consensus process
- Regular team conference calls
- Team / Advisory Board meeting in December 2007
- Reviewed, discussed, brainstormed technologies, issues—detail below in discussion of tasks
- Reviewed and assessed technologies, issues, mitigation strategies
- April 2008 Team Meeting
- Updated Phase 2 work plan reviewed by Advisory Board in June, July 2008
Task 1

• Identify existing and emerging geotechnical materials and systems for ground and roadway improvement for application to: (1) construction of new embankments and roadways over unstable soils, (2) rapid widening and expansion of existing roadways and embankments, and (3) improvement and stabilization of support beneath the pavement structure. In all cases, the need of the roadway or soil to carry construction loads as well as service loads is to be considered.

• Two Products
  - List of technologies
  - Categorized bibliography
### List of Technologies

<table>
<thead>
<tr>
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<td>Injected Light Weight Foam Fill</td>
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<td>Hydraulic Fill + Vacuum Consolidation + Geocomposite drains</td>
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<td>10</td>
<td>Rammed Aggregate Piers</td>
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<td>Geosynthetic Reinforced Embankments</td>
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<td>Vibe-concrete Columns</td>
<td>27</td>
<td>Lightweight Fill, EPS Geofoam, Low-Density Cementitious Fill</td>
<td>43</td>
<td>Chemical Grouting/Injection Systems</td>
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<td>Combined Soil Stabilization, Sand Cement Columns</td>
<td>28</td>
<td>Column Supported Embankments with or without Load Transfer Mat</td>
<td>44</td>
<td>Beneficial Use of Waste Materials</td>
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<td>Continuous Flight Auger Piles</td>
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<td>Geosynthetic-Reinforced Construction Platforms</td>
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<td>Chemical Stabilization of Subgrades and Bases</td>
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<td>Trenchless Construction</td>
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<td>16</td>
<td>Deep Mixing Methods</td>
<td>32</td>
<td>Mechanical Stabilization of Subgrades and Bases</td>
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</table>
Technology Ratings

- Developed rating systems for a technology’s
  - Degree of Technology Establishment
  - Applicability to each of the Elements
  - Potential contribution to SHPR2 Renewal Objectives: rapid, minimal disruption, long-lived
- Each of the 47 technologies rated for the three elements
Element 1 Top Ten

1. Column Supported Embankments
2. Geosynthetic Reinforced Platforms
3. Continuous Flight Auger Piles
4. Vibro-concrete Columns
5. Stone Columns
6. Deep Mixing Methods
7. Reinforced Soil Slopes
8. Vibrocompaction
9. Rammed Aggregate Piers
10. Light Weight Fills
Element 2 Top Ten

1. Column Supported Embankments
2. Reinforced Soil Slopes
3. Continuous Flight Auger Piles
4. Geosynthetic Reinforced Platforms
5. Vibro-concrete Columns
6. Deep Mixing Methods
7. Stone Columns
8. Light Weight Fills
9. Rapid Impact Compaction
10. Rammed Aggregate Piers
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<td>2. Continuous Flight Auger Piles</td>
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<td>8. Vibrocompaction</td>
<td>8. Light Weight Fills</td>
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<tr>
<td>10. Light Weight Fills</td>
<td>10. Rammed Aggregate Piers</td>
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</tbody>
</table>
Element 3 Top Ten

1. Intelligent Compaction
2. Geosynthetic Reinforced Platforms
3. High Energy Impact Rollers
4. Mechanical Stabilization of Subgrades
5. Chemical Stabilization of Subgrades
6. Geosynthetics in Pavements
7. Rapid Impact Compaction
8. Onsite Reuse of Recycled Materials
9. Rammed Aggregate Piers
10. Electro-Osmosis
Categorized Bibliography

- Technology Overview
- Site Characterization
- Analysis Techniques
- Design Procedures
- Design Codes
- Construction Methods
- Construction Time
- Equipment/Contractors
- Construction Loads
- Contracting
- Construction Specs
- QC/QA
- Performance Criteria
- Monitoring
- Geotechnical Limitations
- Non-geotechnical Limitations
- Case History
- Environmental Impacts
- Initial Costs
- Life Cycle Costs
- Durability
- Reliability
Task 2

- Identify and discuss technical issues and project development/delivery pros and cons that need to be considered to further encourage widespread implementation of the geotechnical materials and systems identified in Task 1
- From workshop, list of 17 pros and cons to be assessed
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<td>1</td>
<td>Lack of simple, comprehensive, reliable, and non-proprietary analysis and design procedures</td>
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<td>Costs for design, construction, QC/QA, and/or maintenance</td>
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<td>Construction time</td>
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<td>4</td>
<td>Time from installation to full effectiveness</td>
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<td>5</td>
<td>Lack of established engineering parameters or performance criteria</td>
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<td>6</td>
<td>Lack of effective QA/QC procedures</td>
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<td>7</td>
<td>Lack of easy-to-use tools for selecting technology</td>
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<td>8</td>
<td>Technology immaturity</td>
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<td>9</td>
<td>Need for a specific project delivery method</td>
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<td>10</td>
<td>Lack of site characterization information</td>
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<td>Performance uncertainty</td>
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<td>12</td>
<td>Lack of long-term performance data</td>
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<td>Environmental impact of the technology</td>
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Task 3

- Identify performance criteria, and existing and emerging QA/QC procedures to use with the geotechnical materials and systems identified and discussed in Tasks 1 and 2.
- From workshop, five main categories of QC/QA methods to consider; performance criteria specific to technologies
## Task 3

**Individual comments for each technology**

<table>
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<tr>
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<th>Topics</th>
<th>Results/Comments</th>
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Task 4

- Identify and discuss the non-geotechnical project-specific parameters that constrain the full utilization of the application of the identified geotechnical materials and systems
- From workshop, 14 parameters to be assessed
## Task 4

### Issues

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<tbody>
<tr>
<td>1</td>
<td>Lack of knowledge about the technology</td>
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<td>Lack of organizational structure and policies to encourage use of new technologies</td>
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<td>3</td>
<td>External pressures on agency</td>
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<td>4</td>
<td>Lack of qualified contractors, contractor strategies, personnel, materials, and specialty equipment</td>
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<td>5</td>
<td>Proprietary product/process</td>
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<td>6</td>
<td>Liability</td>
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<td>7</td>
<td>Absence of champion or technical leadership</td>
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<td>8</td>
<td>Project conditions (right-of-way, geometry, scale, utilities, and sequence)</td>
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**Task 4 Ratings**
Task 5

- Assemble a panel of highway design and construction professionals and with its help, identify the most promising methods for mitigating the non-geotechnical project-specific parameters identified and discussed in Task 4 that constrain the full utilization of the application of the geotechnical materials and systems identified in Task 1, and develop a work plan for the following activities:
  - Test and evaluate effectiveness of mitigation methods
  - Develop catalogue of materials and systems for rapid renewal projects
  - Develop design procedures, QA/QC processes, and guidance for applying these geotechnical materials and systems
  - Develop methods for estimating the cost of their application
  - Develop sample guide specifications for these geotechnical materials and systems.
Task 5

- Assembled Advisory Board
- Conducted workshop in December 2007
- Conducted Technology Assessments, includes
  - Description of technology
  - Task 2 and 4 ratings
  - Task 3 identification of performance criteria, QC/QA
  - Updated technology ratings
  - Executive Summary
- Development of mitigation strategies
## Revised List of Technologies

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<tr>
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<td>Jet-injection</td>
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<td>Rammed Aggregate Piers</td>
<td>26</td>
<td>Geosynthetic Reinforced Embankments</td>
<td>42</td>
<td>Geo-treatment for subgrade stabilization</td>
</tr>
<tr>
<td>11</td>
<td>Vibro-concrete Columns</td>
<td>27</td>
<td>Lightweight Fill, EPS Geofoam, Low Density Cementitious Fill</td>
<td>43</td>
<td>Chemical Grouting/Injection Systems</td>
</tr>
<tr>
<td>12</td>
<td>Combined Soil Stabilization, Sand Cement Columns</td>
<td>28</td>
<td>Column Supported Embankments with or without Load Transfer Mat</td>
<td>44</td>
<td>Beneficial Reuse of Waste Materials</td>
</tr>
<tr>
<td>13</td>
<td>Continuous Flight Auger Piles</td>
<td>29</td>
<td>Geosynthetic-Reinforced Construction Platforms</td>
<td>45</td>
<td>Geosystems</td>
</tr>
<tr>
<td>14</td>
<td>Augers</td>
<td>30</td>
<td>Onsite Use of Recycled Pavement Materials</td>
<td>46</td>
<td>Geotextiles: Cake Walls</td>
</tr>
<tr>
<td>15</td>
<td>Geotextile Encased Columns</td>
<td>31</td>
<td>Chemical Stabilization of Subgrades and Bases</td>
<td>47</td>
<td>Geosynthetic-Construction</td>
</tr>
<tr>
<td>16</td>
<td>Deep Mixing Methods</td>
<td>32</td>
<td>Mechanical Stabilization of Subgrades and Bases</td>
<td>48</td>
<td>Geosynthetic-Construction</td>
</tr>
</tbody>
</table>
Mitigation Strategies

- Initially 10 Strategic Categories
  1. Promotional
  2. Collaboration
  3. Demonstration/R&D
  4. Specifications and Bidding
  5. Case History/Database
  6. Preparation of Manuals
  7. Internal SHRP
  8. Outreach
  9. Additional Supporting Information
  10. Back Analysis
Mitigation Strategies

- Developed three broad strategies that encompass the original 10
  1. Education and Training
  2. Agency, Industry, and Academic Collaborations
  3. Policy Development
- Determined which strategies addressed which obstacles
- Also determined whether each obstacle is general or project specific, and the degree to which the obstacles interfere with technologies
Phase 1 Unanticipated Findings (Surprises)

- Several of the non-technical, non-project specific obstacles are very important
- Many mitigation measures for these obstacles are outside the scope of this project
## Mitigation Strategies

<table>
<thead>
<tr>
<th>Obstacle</th>
<th>Predominately a Project-Specific Obstacle or a General Obstacle?</th>
<th>Ave. Degree to which Obstacle Interferes with Technologies</th>
<th>Effectiveness of Strategy to Overcome Obstacle</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-1. Lack of knowledge about technologies</td>
<td>General</td>
<td>1.85</td>
<td>Education and Training</td>
</tr>
<tr>
<td>4-2. Lack of organizational</td>
<td></td>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>
Task 6

- Develop a final report for Phase 1 detailing the work conducted in Tasks 1-5 and proposing a work plan for the tasks to be conducted in Phase 2. This report should provide:
  - Searchable documentation of the identified geotechnical materials and systems addressed
    - Categorized bibliography in literature review data base
    - Technology assessments
  - Information on how to locate and access documentations of case histories
    - Contained in categorized bibliography
  - Reference materials and other supporting documentation.
Phase 2 Work Tasks

- Six tasks:
  8. Test the effectiveness of mitigation methods & evaluate their effectiveness
  9. Develop a catalog of materials & systems for rapid renewal
  10. Develop design procedures, QA/QC processes & guidance for geotechnical materials & systems
  11. Develop methods for estimating costs of geotechnical & materials systems
  12. Develop sample guide specifications for geotechnical & materials systems
  13. Final report
Phase 2 Process

- Continue collaborative, consensus process
- Work efforts focused by Elements and Common areas; teams will spearhead efforts, drawing on others as necessary
- Detailed schedule developed to provide benchmarks for task completion
- Annual Team / Advisory Board meetings to review, discuss, brainstorm issues
- Interaction with other renewal groups
Task 8

- Test the effectiveness of these mitigation methods approved and/or amended from Phase 1, and evaluate their effectiveness.
- Mitigation measures identified in Task 5
- Proposed mitigation measures and means for evaluating effectiveness
## Proposed Mitigation Measures

<table>
<thead>
<tr>
<th>Possible Mitigation Methods for Non-geotechnical Obstacles from Task 4</th>
<th>Strategy Employed</th>
<th>Obstacles Addressed</th>
<th>Evaluating Effectiveness of Mitigation Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.a. Conduct focused workshops to bring together key stakeholders for information exchange, including emerging opportunities for contractors</td>
<td>Collaborations</td>
<td>4-1, 4-2, 4-3, 4-4, 4-7, 4-9</td>
<td>Surveys and interviews of participants to determine impact of workshops on practice</td>
</tr>
<tr>
<td>8.b. Survey and interview DOTs to learn which characteristics of DOTs enable use of new technologies, and use the results to develop recommended DOT policies to encourage appropriate use of new technologies</td>
<td>Policy Development</td>
<td>4-2, 4-3, 4-7</td>
<td>Extent of adoption of the policies. Surveys on the impact of the policies on use of soil improvement technologies.</td>
</tr>
</tbody>
</table>
Task 9

- Develop a catalogue of materials and systems for renewal projects.
- Integrate Task 9 with part of Task 10 “to develop . . . Guidance for applying these geotechnical materials and systems” to provide an overall catalogue and guidance system
  - Initial screening for technology selection
  - After screening, provide detailed information on case histories, design methods, QC/QA procedures, specifications, and costs for suitable technologies
  - HTML format for ease of use and ability to port to internet
- Consistent format for capturing existing and future case history information to facilitate future additions to system
Guidance System

Preliminary Evaluation of
Of Site Conditions and
Design/Performance Requirements
from ETL 1110-1-185
Task 10

• Develop design procedures, QC/QA processes, and guidance for applying these geotechnical materials and systems.

• Design procedures
  ❖ Following an 8 step process for review, development, and selection leading to
    ➢ Assessment of existing design procedures
    ➢ Improved design procedures for selected technologies
    ➢ Recommended design procedures for all technologies

• QC/QA procedures
  ❖ Following a 5 step process to develop detailed QC/QA guidelines

• Results incorporated into guidance and selection system
Task 11

- Develop methods for estimating the application costs of these geotechnical materials and systems.
- Key evaluation parameter for assessing use of potential materials and systems
- Two-tier approach
  - Initial feasibility cost estimation
  - Detailed project cost estimates
- Develop cost database
- Results incorporated into guidance and selection system
Task 12

• Develop sample guide specifications for these geotechnical materials and systems.
• Compile, review and adapt existing specifications
• Assess existing specs
• Develop standard formats (in conjunction with R07)
• Select, adapt or develop appropriate guide specs for each technology
  ✓ Include commentary and discussion of user options, as appropriate
• Results incorporated into guidance and selection system
Task 13

- Develop a final report for Phase 2 detailing the work conducted in Tasks 8-12.
- Summary final report will document the entire research effort
  - Reference to stand alone project documents
- Main product: Overall catalogue and guidance system in HTML format for ease of use and ability to port to web
Questions?